

## Chapter 6 Surface Preparation

### 6-1. Introduction

Thermal spray coatings require a very clean surface that is free of oil, grease, dirt, and soluble salts. Surface contaminants must be cleaned with solvents prior to removal of mill scale, corrosion products, and old paint by abrasive blasting.

*a.* Surface preparation is the single most important factor in determining the success of the corrosion protective thermal spray coating system. Abrasive blasting or abrasive blasting combined with other surface preparation techniques is used to create the necessary degree of surface cleanliness and roughness.

*b.* The principal objective of surface preparation is to achieve proper adhesion of the thermal spray coating to the steel substrate. Adhesion is the key to the success of the thermal spray coating.

*c.* The purpose of surface preparation is to roughen the surface, creating increased surface area for mechanical bonding of the thermal spray coating to the steel substrate. The roughening is typically referred to as the anchor pattern or profile. The profile is a pattern of peaks and valleys that is etched onto the steel when high-velocity abrasive blast particles impinge upon the surface.

*d.* Surface cleanliness is essential for proper adhesion of the thermal spray coating to the substrate. Thermal spray coatings applied over rust, dirt, grease, or oil will have poor adhesion. Premature failure of the thermal spray coating may result from application to contaminated substrates.

### 6-2. Solvent Cleaning (SSPC-SP 1)

Solvent cleaning (SSPC-SP 1) is a procedure for removing surface contaminants, including oil, grease, dirt, drawing and cutting compounds, and soluble salts, from steel surfaces by means of solvents, water, detergents, emulsifying agents, and steam. These methods are not designed to remove mill scale, rust, or old coatings. Ineffective use of the solvent cleaning technique may spread or incompletely remove surface contaminants. Three common methods of solvent cleaning are water washing, steam cleaning, and cleaning with hydrocarbon solvents.

*a. Water cleaning.* Low-pressure water cleaning, up to 34,000 kPa (5000 psi)), is an effective means of removing dirt and soluble salt contamination. When used with a detergent or emulsifying agent, the method can be used to remove organic contaminants such as grease and oil. Thorough rinsing with clean water will ensure complete removal of the cleaning agent. If an alkaline cleaner is used, the pH of the cleaned surface should be checked after the final rinse to ensure that the cleaning agent has been completely removed.

*b. Steam cleaning.* Steam cleaning is an effective means of removing dirt, salt, oil, and grease from both coated and uncoated substrates. The method employs a combination of detergent action and high-pressure heated water (138 °C (280 °F) to 149 °C (300 °F) at 11.3 to 18.9 ℓ/min (3 to 5 gpm)). Thorough rinsing with steam or water should be used to remove any deposited detergent.

*c. Hydrocarbon solvent cleaning.* Hydrocarbon solvents used to remove grease and oil are typically petroleum-based distillates as described by ASTM D235 "Standard Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)." Type I - regular (Stoddard Solvent) with a minimum flash point of 38 °C (100 °F). Type II - High Flash Point mineral spirits with a minimum flash point of 60 °C (140 °F)

should be used when ambient temperatures exceed 35 °C (95 °F). Aromatic solvents such as xylene and high flash aromatic naphtha 100 or 150 (ASTM D 3734 Types I and II) are sometimes used when a stronger solvent is needed. The use of aromatic hydrocarbons should be limited because of their generally greater toxicity. Solvent cleaning with hydrocarbon solvents is typically accomplished by wiping the surface with solvent soaked rags. Rags should be changed frequently to afford better removal and to prevent spreading and depositing a thin layer of grease or oil on the surface

### 6-3. Abrasive Blast Cleaning

Abrasive blasting is performed in preparation for thermal spray after the removal of surface contaminants by solvent cleaning. Abrasive blasting is conducted to remove mill scale, rust, and old coatings, as well as to provide the surface profile necessary for good adhesion of the thermal spray coating to the substrate. Conventional abrasive blast cleaning is accomplished through the high-velocity (724 km/h (450 mph)) propulsion of a blast media in a stream of compressed air (620 to 698 kPa (90 to 100 psi)) against the substrate. The particles' mass and high velocity combine to produce kinetic energy sufficient to remove rust, mill scale, and old coatings from the substrate while simultaneously producing a roughened surface. The Society for Protective Coatings (SSPC) and the National Association of Corrosion Engineers (NACE) have published standards for surface cleanliness. These standards and an SSPC supplemental pictorial guide provide guidelines for various degrees of surface cleanliness. Only the highest degree of cleanliness, SSPC-SP-5 "White Metal Blast Cleaning" or NACE #1, is considered acceptable for thermal spray coatings. Paragraph 6-7 discusses these standards in greater detail. Abrasive blast cleaning may be broadly categorized into centrifugal blast cleaning and air abrasive blast cleaning. Air abrasive blast cleaning may be further subdivided to include open nozzle, water blast with abrasive injection, open nozzle with a water collar, automated blast cleaning, and vacuum blast cleaning. Open nozzle blasting is the method most applicable to preparation for thermal spray coating.

*a. Equipment.* An open nozzle abrasive blast-cleaning apparatus consists of an air compressor, air hose, moisture and oil separators/air coolers and dryers, blast pot, blast hose, nozzle, and safety equipment.

(1) Air compressor. The air compressor supplies air to the system to carry the abrasive. Production rate depends on the volume of air that the compressor can deliver. A larger compressor can supply more air and can therefore sustain operation of more blast nozzles or larger blast nozzle diameters.

(2) Air hose. The air hose supplies air from the compressor to the blast pot. The air hose should be as short, with as few couplings, and as large of diameter as possible to optimize efficiency. The minimum inside diameter (i.d.) should be 31.75 mm (1.25 in.) with measurements of 50.8 to 101.6 mm (2 to 4 in.) i.d. being common.

(3) Moisture and oil separators/air coolers and dryers. If not removed, moisture from the air and oil mists from the compressor lubricants may contaminate the abrasive in the blast pot and subsequently the surface being cleaned. Oil/moisture separators are used to alleviate this problem. The devices should be placed at the end of the air hose as close to the blast pot as possible. Separators are typically of the cyclone type with expansion air chambers and micron air filters. Air coolers/dryers are commonly used to treat the air produced by the compressor.

(4) Blast pot. Most blast pots used for large blasting projects are of the gravity-flow type. These machines maintain equal pressure on top and beneath the abrasive. The typical blast pot consists of air inlet and outlet valves, a filling head, a metering valve for regulating abrasive flow, and a hand hole for removing foreign objects from the pot chamber. For large jobs, the pot should hold enough media to blast for 30 to 40 min. For continuous production, a two-pot unit can be used, allowing one pot to be filled while the other operates.

(5) Blast hose. The blast hose carries the air-media mixture from the blast pot to the nozzle. A rugged multiply hose with a minimum 31.75-mm (1.25-in.) i.d. is common. A lighter, more flexible length of hose called a whip is sometimes used for added mobility at the nozzle end of the blast hose. Maximum blast efficiency is attained with the shortest, straightest blast hoses. Blast hoses should be coupled with external quick-connect couplings.

(6) Blast nozzle. Blast nozzles are characterized by their diameter, material, length, and shape. Nozzle sizes are designated by the inside diameter of the orifice and are measured in sixteenths of an inch. A 3/16-in.-diam orifice is designated as a No. 3 nozzle. The nozzle diameter must be properly sized to match the volume of air available. Too large an orifice will cause pressure to drop and production to decrease. Too small an orifice will not fully utilize the available air volume. The nozzle size should be as large as possible while still maintaining an air pressure of 620 to 689 kPa (90 to 100 psi) at the nozzle. Blast nozzles may be lined with a variety of different materials distinguished by their relative hardness and resistance to wear. Ceramic and cast iron lined nozzles have the shortest life. Tungsten and boron carbide are long lived nozzles. Nozzles may be either straight bore or venturi-type. The venturi nozzle is tapered in the middle, resulting in much higher particle velocities. Venturi nozzles have production rates 30 to 50 percent higher than straight bore nozzles. Long nozzles, 127 to 203 mm (5 to 8 in.), will more readily remove tightly adherent rust and mill scale and increase production rates. Worn nozzles can greatly decrease production and should be replaced as soon as they increase one size (1/16 in.).

*b. Blast cleaning techniques.* Proper blasting technique is important in order to accomplish the work efficiently with a high degree of quality. The blast operator must maintain the optimal standoff distance, nozzle angle, and abrasive flow rate. The best combination of these parameters is determined by an experienced blaster on a job-to-job basis.

(1) The blaster should balance the abrasive and air flows to produce a “bluish” colored abrasive airstream at the nozzle which signals the optimum mix. Blasters often use too much abrasive in the mix which results in reduced efficiency. The mix is adjusted using the valve at the base of the blast pot.

(2) The nozzle-to-surface angle should be varied to achieve the optimal blast performance for the given conditions. Rust and mill scale are best removed by maintaining a nozzle-to-surface angle of 80 to 90 deg. A slight downward angle will direct dust away from the operator and improve visibility. The best nozzle-to-surface angles for removing old paint are 45 to 70 deg. The final blast profile should always be achieved with a nozzle-to-surface angle of 80 to 90 deg.

(3) Standoff, or nozzle-to-surface distance, will also affect the quality and speed of blast cleaning. The lower the standoff distance, the smaller the blast pattern will be, and the longer it will take to cover a given area. However, close standoff distances allow for more energy to be imparted to the surface, allowing for the removal of more tenacious deposits such as mill scale. A standoff distance of as little as 153 mm (6 in.) may be necessary for the removal of tight mill scale and heavy rust deposits. Higher standoff distances, on the order of 457 mm (18 in.), are more efficient for the removal of old loosely adherent coatings.

*c. Abrasive media type and selection.* The selection of the proper blast media type and size is critical to the performance of the thermal spray coating. Blast media that produce very dense and angular blast profiles of the appropriate depth must be used. An angular blast media must always be used. Rounded media such as steel shot, or mixtures of round and angular media will not produce the appropriate degree of angularity in the blast profile. The adhesion of thermal spray coatings can vary by an order of magnitude as a function of profile shape and depth. Thermal spray coatings adhere poorly to substrates prepared with rounded media and may fail in-service by spontaneous delamination. Hard, dense, angular blast media such as aluminum oxide, iron oxide, and angular

steel grit are needed to achieve the depth and shape of blast profile necessary for good thermal spray adhesion. Steel grit should be manufactured from crushed steel shot conforming to SAE J827. Steel grit media composed of irregular shaped particles or mixtures of irregular and angular particles should never be used. Only angular steel grit should be used. New steel grit should conform to the requirements of SSPC-AB 3, "Newly Manufactured or Re-Manufactured Steel Abrasives." Various hardnesses of steel grit are available but generally grit with Rockwell C hardness in the range of 50 to 60 is used. Harder steel grit (Rockwell C 60 to 66) may also be used provided that the proper surface profile is obtained. Steel shot and slag abrasives composed of all rounded or mixed angular, irregular, and rounded particles should never be used to profile steel for thermal spraying. Table 6-1 shows the recommended blast media types as a function of the thermal spray process and coating material.

<b>Table 6-1 Recommended Blast Media for Thermal Spray Surface Preparation</b>		
Thermal Spray Material	Thermal Spray Process	Blasting Media
Aluminum, zinc, and 85-15 zinc-aluminum	Wire flame spray	Aluminum oxide Angular steel grit
Aluminum, zinc, and 85-15 zinc-aluminum	Arc spray	Aluminum oxide Angular steel grit, angular iron oxide
Aluminum and zinc	Powder flame spray	Aluminum oxide Angular steel grit

*d. Blast profile.* Thermal spray coatings are generally more highly stressed than paint coatings and as such require a deeper blast profile to dissipate the tensile forces within the coating. In general, the greater the thickness of thermal spray coating being applied, the deeper the blast profile that is required. The minimum recommended blast profile for the thinnest coatings of zinc and 85-15 zinc-aluminum (100 to 150  $\mu\text{m}$  (0.004 to 0.006 in.)) is 50  $\mu\text{m}$  (0.002 in.). Thicker coatings of zinc and 85-15 zinc-aluminum, 250  $\mu\text{m}$  (0.010 in.) or greater, require a minimum 75- $\mu\text{m}$  (0.003-in.) profile. A 125- $\mu\text{m}$ -(0.005-in.-) thick aluminum coating requires a minimum surface profile of 50  $\mu\text{m}$  (0.002 in.), and a 250- $\mu\text{m}$  (0.010-in.) aluminum coating requires a minimum 62.5- $\mu\text{m}$  (0.0025-in.) profile. The specifier should specify the maximum and minimum surface profile required for the thermal spray coating. The maximum profile for thicker thermal spray coatings should not exceed approximately a third of the total average coating thickness. As a general rule, the maximum blast profile should be 25  $\mu\text{m}$  (0.001 in.) greater than the specified minimum profile depth. Table 6-2 shows the recommended minimum and maximum blast profile depths for the thermal spray systems described in CEGS-09971. Table 6-3 shows typical surface profiles produced by selected steel grit abrasives.

*e. Blasting with reusable media.*

(1) Durable reusable blast media are now commonplace in industrial maintenance coating. The extensive use of blasting enclosures used to contain paint and blasting debris has made the use of reusable abrasives more economical for field applications. Reusable abrasives require the use of a reclaiming and recycling system. Commonly used recyclable abrasives that are appropriate for use in preparing steel for thermal spray include steel grit, aluminum oxide, and iron oxide. Iron oxide, aluminum oxide, and steel grit may be reused about 4, 6 to 8, and 100+ times, respectively. Because it is more economical, steel grit is much more likely to be used for fieldwork than are other reusable media.

(2) Control of the working mix of abrasive is critical to maintaining the quality of the blast. The working mix should be sampled frequently and subjected to a sieve analysis to determine the particle size distribution. The distribution can be used to determine the frequency of make-up additions to the working mix. If the mix is allowed to become depleted of larger particle sizes, then the required surface profile depth will not be achieved.

**Table 6-2**  
**Recommended Surface Profiles for Thermal Spray Systems**

Thermal Spray System Designation	Thermal Spray Material	Minimum/Average Thermal Spray Thickness, microns (in.)	Minimum/Maximum Surface Profile, microns (in.) <sup>a</sup>
1-Z	Zinc	125/150 (0.005/0.006)	50/75 (0.002/0.003)
2-Z	Zinc	250/300 (0.010/0.012)	62.5/87.5 (0.0025/0.0035)
3-Z	Zinc	350/400 (0.014/0.016)	75/100 (0.003/0.004)
4-Z-A	85-15 zinc-aluminum	125/150 (0.005/0.006)	50/75 (0.002/0.003)
5-Z-A	85-15 zinc-aluminum	250/300 (0.010/0.012)	62.5/87.5 (0.0025/0.0035)
6-Z-A	85-15 zinc-aluminum	350/400 (0.014/0.016)	75/100 (0.003/0.004)
7-A	Aluminum	100/125 (0.004/0.005)	50/75 (0.002/0.003)
8-A	Aluminum	200/250 (0.008/0.010)	62.5/87.5 (0.0025/0.0035)

<sup>a</sup> As measured by ASTM D4417, Method C (replica tape). This method measures the average maximum peak to valley height.

**Table 6-3**  
**Typical Surface Profiles for Selected Steel Grit Abrasives<sup>a</sup>**

Steel Grit Size	Surface Profile, 0.001 in. <sup>b</sup>
G50	1.6 ± 0.3
G40	2.4 ± 0.5
G25	3.1 ± 0.7
G14	5.1 ± 0.9

<sup>a</sup> Steel grit is crushed steel shot conforming to SAE J827. Grit hardness is 55-60 Rockwell C.

<sup>b</sup> As measured by ASTM D4417, Method C (replica tape). This method measures the average maximum peak to valley height.

This may lead to poor thermal spray coating adhesion and premature failure. Different abrasive materials wear out at different rates, usually given as consumption rates in pounds per hour. In theory, new abrasive can be added at a rate equal to the consumption rate. A continuous system of abrasive replenishment is the preferred method of maintaining the proper working mix and should be required on all jobs where recyclable abrasives are used. Maintaining a uniform working mixture also requires the removal of all particles below a given minimum size, which is the smallest size that is still effective in the cleaning operation. Recycled steel grit should meet the cleanliness requirements of SSPC-AB 2.

(3) The size and type of abrasive blast system used with recyclable media must be properly selected. Contractors employing undersized equipment or an inappropriate type of equipment for the job are not likely to produce a quality surface with the correct profile. In general, the contractor should employ midsize, 9 to 13.5 metric tons per hour (10 to 15 tons per hour), or large, >13.5 metric tons per hour (15 tons per hour), blast media recycling systems. Midsize and large blast media recycling systems typically have better multistage abrasive cleaning systems that remove dust, debris, and small particles.

*f. Centrifugal blast cleaning.* Centrifugal blast cleaning is commonly used in fabrication shops. The method is generally faster and more economical than open abrasive blasting. The method involves the conveying of the steel through a blast cabinet or enclosure where high-speed rotating wheels with blades propel abrasive particles at the steel. The blasting debris falls to the bottom of the chamber where it is reclaimed, cleaned, and then recycled. The degree of cleanliness achieved is determined by the abrasive velocity and the conveyor speed. Steel shot is usually used in centrifugal blast machines. For thermal spray coatings, a subsequent profiling blast using an angular media is required to achieve the desired blast profile depth and angularity. Centrifugal blast cleaning machines are now available for fieldwork as well, but their use is not widespread.

*g. Cleaning after blasting.* Cleanliness after abrasive blasting is important. Any remaining traces of spent abrasive or other debris must be blown, swept, or vacuumed from the surface prior to thermal spray application.

A hard-to-see layer of abrasive dust may adhere to the substrate by static electric charge and must be removed. The thermal spray applicator may accomplish this by triggering just the compressed air from the flame or arc gun. Scaffolding, staging, or support steel above the thermal spray coating area must also be cleaned prior to application to prevent debris from falling onto the surfaces to be coated. Blasting and thermal spray should not occur simultaneously unless the two operations can be adequately isolated to prevent contamination of the thermal spray surfaces.

*h. Time between blasting and thermal spraying.* After completion and inspection of the final profiling blast, the steel substrate should be thermal sprayed as soon as possible. A maximum period of 4 hr is generally allowed to elapse between the completion of blast cleaning and thermal spraying. This period should allow adequate time for the changeover from blasting to thermal spraying. Thermal spray should commence prior to the appearance of any visible rust bloom on the surface. Foreign matter such as paint overspray, dust and debris, and precipitation should not be allowed to contact the prepared surfaces prior to thermal spraying. Under no circumstances should the application of thermal spray be allowed on rerusted or contaminated surfaces. In some cases it may be possible to apply only a single spray pass or some other fraction of the total thermal spray system within 4 hr of blasting. This single layer must cover the peaks of the surface profile. The partial coating is intended to temporarily preserve the surface preparation. Before applying additional sprayed metal to the specified thickness, the first layer of coating should be visually inspected to verify that the coating surface has not been contaminated. Any contamination between coats should be removed before any additional material is applied. The remaining coating should be sprayed to achieve the specified thickness as soon as possible. In some cases it may be possible to hold the surface preparation for extended periods using specially designed dehumidification (DH) systems. These systems supply dry air to a blast enclosure or other contained air space. The dry air prevents the reappearance of rust for extended periods of time and allows for thermal spray jobs to be staged in a different fashion. DH systems may be particularly useful for jobs in very humid environments, which are typical of many Corps facilities during the spring through fall maintenance season. These areas typically have dense morning fog and hot humid afternoons. Holding the quality of blast needed for thermal spray coatings would be difficult under such conditions without the use of DH.

#### **6-4. Minimizing Surface Preparation Costs**

*a. Strip blasting.* Combined methods of surface preparation may be used to reduce the overall cost of surface preparation. The most common method of combined surface preparation is the use of strip blasting with an inexpensive abrasive. Strip blasting may be used to remove aged coatings or to remove tightly adherent mill scale. Steel shot is particularly effective for removing mill scale. Steel, copper, nickel, and coal slags and garnet and zircon abrasives may all be used to remove old coatings. Silica-containing materials, including silica and mineral sands, glass beads, flint, and novaculite, should be avoided because of health issues surrounding the use of abrasives containing silica.

*b. Profile blasting.* Profile blasting must be performed after strip blasting in all cases. It is not necessary for profile blasting to occur before light rerusting of the surface occurs. The strip blasted surface should, however, be protected from the deposition of contaminants such as grease and oil that may not be removed during the final profiling blast. Under some circumstances, it may be economical to perform strip blasting using ultrahigh-pressure water jetting. This method uses high pressure water, >170,000 kPa (25,000 psi), to remove old coatings. The method will not, however, remove mill scale or tightly adherent rust. The combination of ultrahigh-pressure water jetting and profile blasting probably will not be economical for surfaces with mill scale. Pressurized water cleaning systems are used frequently in shipyards and are most likely to be encountered in strip and profile applications at these facilities.

## 6-5. Preparing Heat-Affected Zones

Heat-affected zones associated with steel welding and cutting operations can produce surfaces that are difficult to clean and thermal spray. Welding and cutting operations produce enough heat to anneal, or harden, the surface of the steel. In some cases, the steel may be so hard as to prevent adequate profiling during abrasive blasting.

It is recommended that all heat-affected zones first be ground with a disk wheel grinder prior to profile blasting. For example, the hardened or carburized layer on a flame-cut girder flange should be ground off before abrasive blasting for profile. Weld spatter not removed by blasting should be removed with impact or grinding tools, and the areas should be reblasted prior to thermal spraying.

## 6-6. Preparing Pitted Steel and Edge Surfaces

*a. Pitted Steel.* Heavily corroded, deeply pitted surfaces are difficult to prepare for thermal spray coating. Wide, shallow pits do not pose any particular problem, but deep and irregular shaped pits can pose a problem. Pits with an aspect ratio of greater than unity (as deep as they are wide) should be ground with an abrasive disk or other tool prior to blasting. Pits with sharp edges, undercut pits, and pits with an irregular horizontal or vertical orientation must be ground smooth prior to abrasive blasting. Grinding does not need to level or blend the pit with the surrounding steel but should smooth all the rough and irregular surfaces to the extent necessary to allow the entire surface of the pit to be blasted and coated. Nozzle-to-surface angles of 80 to 90 deg are optimal for cleaning pits. Heavily pitted steel on bridges or in other environments where soluble salt contamination is likely should be cleaned with high-pressure water after grinding to ensure that salt contaminants are removed from the pits.

*b. Edge Surfaces.* Sharp edges also present problems in achieving adequate surface preparation and coating. As a general rule, all sharp edges should be ground prior to blasting to a uniform minimum diameter of 3 mm (1/8 in.).

## 6-7. Surface Preparation Standards and Specifications

SSPC and NACE have developed blast cleaning standards and specifications for steel surfaces. More detailed information is available on blast cleaning specifications in the SSPC "Painting Manual, Volume 2, Systems and

*a. SSPC-SP 5 or NACE #1.* SSPC-SP 5 and NACE #1 describe the condition of the blast-cleaned surface when viewed without magnification as free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter.

*b. SSPC VIS 1-89.* SSPC VIS 1-89 supplements the written blast standards with a series of photographs depicting the appearance of four grades of blast cleaning over four initial grades of mill scale and rust. The last two pages of the standard depict a white metal blast-cleaned substrate achieved with three different types of metallic abrasives and three types of nonmetallic abrasives. The resulting surfaces have slight color and hue differences caused by the type of media used.